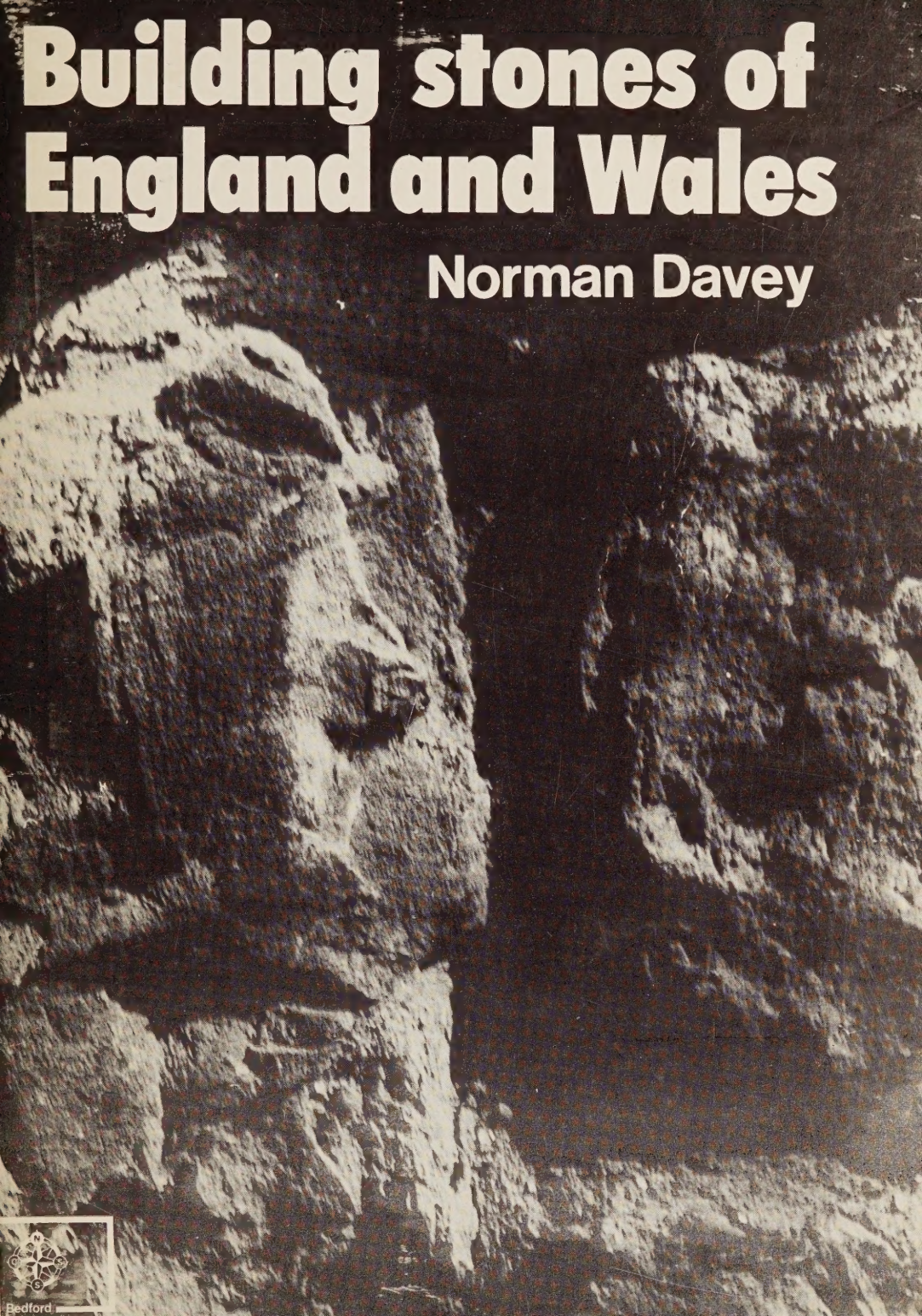
Building stones of England and Wales

Norman Davey



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Introduction

Stone is our most beautiful and enduring material for building and in England and Wales we are particularly fortunate in having abundant supplies of it. Many examples of its use have survived from prehistoric times. The stone circles at Avebury and Stonehenge in Wiltshire are but two which bear testimony to this. In a particular locality, and certainly in any particular quarry, the type and quality of the stone may vary greatly, and the selection of stone suitable for building must depend on a number of factors such as physical structure, whether, for example, the material is laminated or occurs in the quarry in homogeneous beds of sufficient thickness to provide blocks of reasonable thickness and size. The chemical composition is important; to know whether the stone will weather well, or will not interact detrimentally with other materials which come into contact with it. Limestone, for example, should not, as a general rule, be laid against sandstone for the two materials may interact chemically. The colour and texture of the stone may also influence its choice. Even in one quarry the colour of the beds of stone may vary, offering a wide range of choice to the architect. He may prefer one colour tone to another, to enhance the appearance of his building, and to harmonise with its surroundings.

Due to difficulties of transport long ago, stone was often limited to a large extent to local use. Therefore a study of early churches in a locality, or of other historic buildings such as monastic structures, castles and cathedrals, will often provide very valuable information on the type and durability of stone. It may also be possible to trace the location of the quarry whence the stone was obtained and to procure samples for reference. This in itself would form a most valuable study. People living in the area may be able to give information on local quarries, and a study of ancient building records preserved in county record offices and elsewhere may also lead to interesting results.

Many different kinds of rock have been used for building, but they fall broadly into two main groups, the primary, or igneous, rocks, such as granite, syenite, diorite, dolerite, and basalt, formed by cooling and solidification of a molten magma; and the secondary, or sedimentary, rocks such as limestones and sandstones, formed by the disintegration and decomposition of the primary rocks and the subsequent deposition and consolidation of the products in a stratified form.

There is a further group of rocks termed metamorphic. They are derived from pre-existing solid rock masses, either igneous or sedimentary, by the action of heat, pressure, or chemical fluids acting separately or together to form a distinctive new type of stone. For example, gneiss, which generally has the same composition as granite, is derived by crystallisation from igneous rocks; quartzite is similarly produced by crystallisation from sandstone; marble by metamorphism from limestone; and slate is derived from argillaceous sediments or fine-grained volcanic ashes by metamorphism.

Igneous Rocks

The igneous rocks are divided into three groups: Plutonic, Hypabyssal, and Volcanic. Those in the Plutonic group include granite, syenite, diorite and gabbro, and they occur in nature as major intrusions of material which solidified well below the earth's surface under conditions of slow cooling. They are completely crystalline and coarse grained. The Hypabyssal group, including quartz porphyry, syenite porphyry, and dolerite, occur naturally as minor intrusions of material which solidified below the earth's surface in small wall-like or sheet-like bodies known respectively as dykes or sills. They are either completely or almost completely crystalline and fine grained. Rocks of the Volcanic group include ryolite, obsidian, trachyte, andesite and basalt. They exist as surface extrusions of materials discharged at the surface of the earth, or on the seabed, and are incompletely crystalline and very finely grained or are non-crystalline (glassy). Associated with volcanic igneous rocks are a number of fragmental rocks which

may almost be classed as sedimentary rocks. They include volcanic agglomerates or coarse tuffs, tuff and ashes and trass. Clearly igneous rocks form a complex group of materials not all suitable for building purposes. Although geologically granite is a closely defined type of rock, the name has been applied rather loosely to many other igneous rocks by the stone industry. The more important quarries for granite are situated in Cornwall and Devon, where the material is mostly muscovite (containing white mica) biotite (containing black mica) granite, and in Westmoreland and Wales where the material is mostly porphyritic granite.

Sedimentary Rocks

Of the sedimentary rocks, sandstones consist essentially of the more durable fragments of igneous rocks, such as quartz, felspar and mica cemented together by siliceous matter, calcium and magnesium carbonates, iron compounds, or clay. They are formed by the degradation of the igneous rocks by weathering processes, followed by the transportation of the weathered fragments by wind and water, and their deposition on land or in water where their partial or complete consolidation may occur by the introduction of cementing material in solution, and by subsequent pressure. Depending on the type of cementing material sandstones are classed as siliceous (like Darley Dale stone of the carboniferous system), calcareous, or dolomitic (like Red Mansfield stone of Permian system in Nottinghamshire), ferruginous, or argillaceous (clay cemented). Their texture varies from coarse to very fine, particularly in those samples which were formed from wind-blown deposits. Siliceous sandstones, like those from Darley Dale and Stancliffe are very durable. Calcareous and dolomitic sandstones which, as their name implies, are cemented with calcium carbonate and magnesium carbonate respectively, are generally less durable than the siliceous type. Sometimes sandstones are classified according to their geological age rather than on a lithological basis; for example, Jurassic sandstone, Cretaceous sandstone, and Triassic sandstone, Permian sandstone, or Carboniferous sandstone, but the classification based on the type of cementing material is perhaps more useful when choosing stone for building construction.

Limestones consist essentially of calcium carbonate formed either by precipitation from sea water as small spheroidal (oolitic) calcareous grains, or by the accumulation of the shells and skeletons of marine organisms. The deposits are further cemented together by calcium carbonate in solution. Limestones can be grouped lithologically according to their composition and physical characteristics as follows. Shelly limestone (like Hopton Wood stone from Middleton, near Wirksworth, Derbyshire, of Carboniferous system) containing shells of marine organisms; crinoidal limestone, containing fragments of stems and 'arms' of crinoids, the so called 'sea lilies', foraminiferal limestone (like Beer stone from South Devon) containing microscopic marine animals in shells, known as foraminifera; coral limestone, containing skeletons of coral and calcareous algae, stromato poroids, and mollusca (of Devonian and Carboniferous system); bryozoa limestone (like the magnesian limestone of Yorkshire) containing bryozoa or mosslike animals; dolomitic and magnesian limestone (like the Car-

boniferous limestones of Derbyshire and South Wales), formed either by the alteration of normal limestone or chemically deposited rock (like Mansfield and Bolsover Moor stone of the Permian system); oolitic limestone, like Ketton stone, often called oolite, or roestone, composed mainly of small spherical bodies (oolites) consisting of concentric rings of calcium carbonate deposited around sand grains, or fragments of shell, or coral, and cemented together with crystalline calcite (calcium carbonate); tufa, known to the Greeks as *poros*; and travertine limestone, often porous, formed by the redeposition of calcium carbonate taken up in solution by water flowing through older calcareous rocks.

Geologically, tufa and travertine are the more recent of the limestones; and they occur in localised deposits, around springs.

As in the case of sandstones, limestones may also be classified according to their geological age, eg Permian limestone, Rhaetic and Triassic limestones, Carboniferous limestone and Devonian limestone. Some of the limestones are particularly hard, and can be highly polished to resemble marble.

Purbeck 'marble' from the Purbeck beds, near the top of the Upper Jurassic rock in the Isle of Purbeck, near Swanage has been used since Roman times and was a favourite material with English mediaeval architects, particularly for slender clustered columns and sepulchral monuments. It contains myriads of shells of the freshwater snail *Paludina carinifera,* embedded in a greenish, or bluish-grey limestone, It can be easily confused with some varieties of the Sussex marble, which occurs in thin beds in the Wealden clay, in the Petworth area, which is of Lower Cretaceous system. It contains shells of *Paludina,* but principally *P. sussexienis* and *P. fluviorum.* Examples of the use of Purbeck marble can be seen in the columns of Westminster Abbey, in part of the Shrine of Edward the Confessor, and in the cathedrals of Lincoln, Winchester, Worcester and Salisbury. Sussex marble was used for the altar stones and episcopal chair in Canterbury Cathedral.

Other 'marbles' or hard limestone, able to take a high polish have been obtained from various localities. At Ashburton, in Devon, a limestone of Devonian age has given a 'marble' dark grey to black in colour, with white and red patches and veins. Other colourful rocks with reddish tints have come from the Torquay and Newton Abbot area. The Petitor quarry at Torquay, for example has produced three varieties known as Petitor Grey and Pink, Petitor Grey (Petitor Spot) generally grey in colour but containing many fossils, and Petitor Pink, predominantly pink in colour with brown and red markings, with veins and patches of grey and yellow. From Ketley, near Yealmton, also in Devon has come a green 'marble', also of Devonian system.

In Somerset the best known 'marbles' are the grey and green ones of the Quantocks, the black 'marble' of Cheddar, and the brown 'marble' nearer Bristol. Farther north in Derbyshire are the carboniferous 'marbles' such as Hopton Wood, from Matlock, and Hadene Derbyshire Fossil, the former being a pleasant cream colour. In the past black limestone from Ashford and a mottled grey limestone from Monyash, also in Derbyshire, have been used as 'marbles'.

In Westmoreland a white 'marble' was quarried in the eighteenth century

near Kendal. It was veined with red and other tints. Also near Ambleside was quarried a green coloured 'marble' veined with white, and an almost black one near Kirby Lonsdale.

Some types of limestone and sandstone, and calcareous sandstone are of a fissile nature and can be easily split into thin layers, from which roofing tiles can be formed. Sometimes the freshly dug slabs of stone, or 'pendles', were laid flat on the ground and left until the winter frosts commenced to split them horizontally. Sometimes they had to be left throughout the whole winter for this to happen and they had to be wetted in order to encourage splitting. A tile-maker completed the splitting by means of a special hammer with a sharp curved edge. Then he rested the pieces of stone upon a horizontal iron blade mounted in a heavy block, trimmed them to the required shape, and pierced a hole in them with a pick, at a suitable point near the top so that they could be hung to the roof battens by oak pegs or clouts.

The technique is very old. The Romans used many stone roofing tiles, some almost oval in shape, others four, five, or six-sided pointed or slightly rounded at their lower extremity. The Romans went to some trouble to obtain suitable materials. For example, for their villa at Chedworth, in Gloucestershire, they used not only the local limestone, but also sandstone from the Forest of Dean. The craft has continued in England and Wales since the Roman times, but on a much reduced scale.

Rocks suitable for tile making occur in the following geological strata:

(a) Cambrian and Silurian, with its highly micaceous sandstone of the Upper Silurian (Ludlow group) quarried to the north of Amman-ford in South Wales, and the slate stone, known as 'Green Slate' rock, quarried at Honister Crag, near Keswick.

(b) Devonian, producing the fissile sandstone of the Old Red Sandstone in South Wales.

(c) Carboniferous, producing thin flaggy sandstone, from Wales, Derbyshire, Lancashire and Yorkshire.

(d) Jurassic, rocks from the Lias formation in Somerset and Shropshire; from marl-stone in Wiltshire; from calcareous sandstone (Duston slate) from Duston in Northamptonshire; from the calcareous sandstone at the base of the Great Oolite at Stonesfield, between Charlbury and Woodstock in Oxfordshire, Eyford and Kyneton Thorns in Gloucestershire, and other parts of the Cotswold area; from thin limestone of the Forest Marble, which occurs in several small quarries in Gloucestershire; from hard siliceous limestone at Brandsby, Yorkshire, and from the Lower Purbeck beds in Dorset.

(e) Cretaceous, producing Horsham Stone of the Wealden beds in Sussex.

Metamorphic Rocks

A third group are the metamorphic rocks. These are formed from either igneous or sedimentary rocks which have been subjected to the effects of heat or pressure, or of both these combined. Their form has therefore been changed, igneous rocks into gneisses, clays into slates, sandstones into quartzites and limestones into marbles. The only rocks so formed and used in building are the slates and marbles. Although slate is extensively

quarried in England and Wales, marbles are scarce. Most of the so-called marbles are limestones which are capable of receiving a high polish, for example, Purbeck marble and Sussex marble. They both contain fossils which of course, would have disappeared had the limestone undergone the re-crystallisation which occurs with true marbles.

Slate is a sedimentary argillaceous stone produced by metamorphism of primary or igneous rocks. The original material in the form of fine clay, sometimes with sand or volcanic dust, was deposited under water and consolidated by vertical pressure into mudstone and shale. In this condition the sedimentary particles were cemented by carbonates of lime and magnesia, by kaolin, or by various iron compounds. Intense heat and great lateral pressure subsequently converted the product into slate, the kaolin and felspar of the original sediment being transformed into sericite, a potash bearing mica which had a crystalline form of minute overlapping flakes and fibres in planes running at right angles to the direction of pressure. This structure imparted great strength and elasticity to the material. The cleavage planes formed in the material do not necessarily coincide with, and may in fact be quite oblique to, the sedimentation beds formed during the deposition of the original material.

Limestone Quarries

Of the stones for building, limestone is that most widely used. It occurs in a band stretching across England from East Devon and Dorset, to Lincolnshire and into Yorkshire (Figure 1). The stone varies in structure, texture and colour at different points along this ridge and the variations in quality are reflected in the character and appearance of the buildings in the towns and villages from south to north.

Limestone from Beer on the coast of Lyme Bay, near Seaton in East Devon, has been used locally for many years, particularly for churches, as for instance for the tower of Sidmouth Church dating from the fifteenth century. The stone was shipped to London where it was used in 1347 for the King's Chapel at Westminster, and shortly after for work at the Tower of London and later for some parts of Christopher Wren's cathedral of St Paul's. Transport by water was much easier and less costly than by road and trackway, and stones quarried along the coastline, as at Beer, and in river estuaries and valleys were often delivered to sites some hundred miles away. Beer stone was also used at Exeter Cathedral, being carried there directly by boat along the coast and up the River Exe.

Eastward along the coast are the very important quarries of Portland stone, situated for the most part on the Isle of Portland itself. The stone of the Jurassic Period is a shelly oolitic limestone, greyish-white, or cream in colour. The quarries are very extensive and deep, often 40 feet or more. The earliest workings were naturally on or near the cliff face, so that the stone could be loaded directly into boats. Some of the quays, built in the eighteenth century specially for loading stone still exist, as for example Forbes Pier and Kings Pier. The principal beds of the limestone, are the Whitbed, a fairly uniform and close grained stone, the Roach bed of shelly and rather coarse textured stone, often used for ashlar work, and the Basebed of more even textured stone, fine grained and comparatively free from shell. Beneath

the Basebed some attractive crystalline limestone, called Pericot, has been worked more recently and is suitable for slab walling.

Portland stone has been used for centuries. In the fourteenth century it was used, like Beer stone, at Exeter Cathedral, being transported by ship. It was in the seventeenth century after the Great Fire that it came into great prominence for rebuilding London. Sir Christopher Wren used it in the reconstruction of St Paul's Cathedral, and for the fifty or so towers and turrets of the City churches. He also used it for Greenwich Hospital. Other random examples of its use in London are Horse Guards, Somerset House, Bank of England, National Gallery and the Law Courts. Inigo Jones used it for the famous Banqueting House in Whitehall. A more recent and different use was for the new Waterloo Bridge, where the Portland stone was used in vertical courses, for facing the structure. The headquarters of the Royal Institute of British Architects in Portland Place, London and the Royal Air Force Pavilion at Brookwood Cemetery are two more examples worthy of note.

The Isle of Purbeck, also in Dorset, produces the famous so-called 'Purbeck marble'. It is a limestone of the Jurassic Period, consisting of a tough conglomerate of freshwater snail shells, varying in colour from light grey to dark grey, and to blue, and is capable of taking a high polish. The stone was used by the Romans and slabs of it have been found on some of their town sites as far away as Viroconium (Wroxeter) near Shrewsbury. It has also been used in church building since the late twelfth century particularly for slender detached shafts, foliated capitals, column bases, string courses

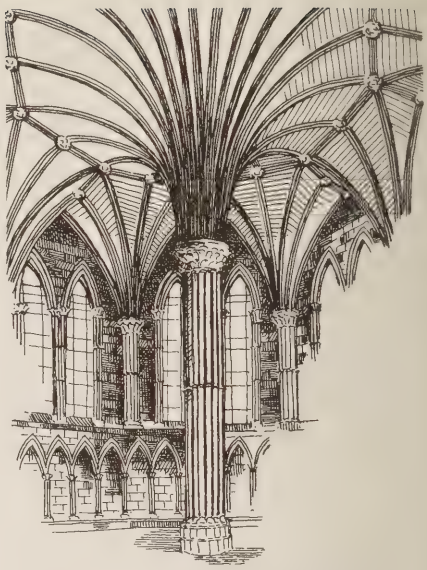

Fig. 4 Chapter House, Lincoln Cathedral.

and for flooring. Many examples of its use can be seen throughout the country. One is illustrated in Figure 4, which shows the clustered columns of Purbeck marble in the Chapter House at Lincoln Cathedral. This stone came from a quarry at Worth Matravers, whose quarries are still operating. Keates quarry and St Aldhem's quarry are two others. In fact quarries, and many old workings, abound in the South Hills from Swanage to Worth Matravers, and along the coast from Anvil Point to St Albans Head. Quarries are also still working at Langton Matravers, Herston, near Swanage, and at Swanage itself. There is hardly a church of the thirteenth and fourteenth century throughout England that does not contain some architectural details in Purbeck marble. Ely, Exeter, Norwich, Lincoln and Salisbury cathedrals are but a few examples, but

the great pillars of the nave at Westminster Abbey, built between 1387 and 1404 are notable. A local example of its use is in part of the Norman church of St Nicholas at Studland, not far from Swanage.

A considerable amount of limestone has in the past been quarried in the Isle of Wight. Much of it has been used in buildings on the island. For example, stone quarried at Binstead was used in the twelfth century for some neat squared masonry at Carisbrook Castle, and later during repairs Bonchurch stone was used there for some large quoins. Bembridge limestone was used for Yarmouth Castle, and it was from Yarmouth that much of the Isle of Wight stone was shipped into Hampshire and the Southern counties. Binstead stone, and some from Ventnor, was used for Arreton Manor, built about 1612, with an east wing dating from the fourteenth century. Shipped to the mainland, Binstead stone and Quarr stone were used for facing the Norman keep of Arundel Castle. Stone from Quarr was also used for Beaulieu Abbey founded by King John in 1204 for Cistercian or White monks. Stone from Bonchurch and Bembridge was used at Porchester Castle in 1397, and some from Selborne at Winchester Castle. When William of Wykeham carried out repairs to the nave of Winchester Cathedral he obtained stone from Binstead, and commissioned the Abbot of Quarr Abbey to transport it by sea. The Quarr quarries were particularly interesting for they were close to and owned by Quarr Abbey which was founded in 1132 by Baldwin de Redvers, Earl of Devon, for Benedictine monks.

Somerset produces several important grades of limestone. The mountain limestone of the Carboniferous series stretches from the west of Bristol along the Mendip Hills to the famous Cheddar Gorge, where the massive formation is most spectacular. Some of the stone is worked at the Battscombe quarry, near Cheddar. It is light grey to pink in colour. Limestone of the Jurassic Oolite series comes from Doulting near Shepton Mallet and is light brown in colour. The St Andrew quarry at Doulting supplied the stone for the façade of Wells Cathedral, and can be seen to great advantage there particularly on the west front. More recently Doulting stone has been used for the new government buildings in Whitehall, London, and for facing some of the bridges on the M2 and M5 motorways, at Warndon junction, near Worcester, for example. Another type of limestone is Ham Hill Stone from Ash near Martock, which has been worked since Roman times. A shelly limestone of the Jurassic Lias series, fawny brown in colour, it was used in the beginning of the fourteenth century for building the Priory at Stoke-sub-Handon in Somerset, now in the care of the National Trust, and later on for the beautiful Montacute House, also a National Trust property. This latter house was built by Sir Edward Philips between 1588 and 1601. At the church of St Mary the Virgin at Cerne Abbas, Ham Hill stone was used for the tower and front of the church and for the walls of the Lady Chapel. Similar lias limestone has been dug at Charlton Mackrol.

Limestone from the Dundry quarries to the south-west of Bristol was used for many of the buildings of mediaeval Bristol. St Mary Redcliffe is a particularly fine example of its use, and should be visited. Queen Elizabeth I in 1574 aptly described the church as

the 'fairest, the goodliest and most famous church in England'. Stone similar to that from Dundry was quarried at Felton, Broadfield and elsewhere; and there are many disused quarries in the Mendip and Quantock Hills.

Perhaps the most famous Somerset stone is that from Bath, also used since Roman times. Bath is a most beautiful city of limestone buildings. It was in 1715 that Ralph Allen came to Bath, and realised the great potential there was in the Bath stone. In 1725, the River Avon was made navigable to Bristol and Allen commenced the systematic quarrying of limestone at Combe Down and later at Hampton Down. He collaborated with the speculative architects John Wood (1704-1764) and his son John (1727-1782). It was the Woods who built the beautiful buildings in Bath. John Wood senior, who began to build in 1728, had the financial backing of wealthy landowners. The good quality of his work using Bath stone was such that it was not long before the whole city of Bath was graced with streets and squares, and rows of houses, laid out with great skill and elegance. Particularly noteworthy are the Circus built in 1754 by John Wood senior, with houses embellished with pillars of Corinthian, Doric and Ionic orders; and the Royal Crescent built in 1769 by his son with its beautiful crescent of stone houses adorned with a colonnade of Ionic pillars, and supporting a cornice with a rich entablature. There are other streets of note where buildings of stone can be studied, like Queen's Square, Lansdown Crescent, Cavendish Crescent, Camden, Portland and Somerset Places, Paragon, Belmont, and Belvedere.

A lot of the stone came from the Combe Down quarries where working was both opencast and by underground mining, but the other quarries in Bath are now closed, and Bath stone now comes mainly from quarries in Box and Corsham. In the early days the stone from Box and Corsham was transported by wagon to Bath, and from there by barge to Bristol where much was exported. Although oolitic limestone of the Jurassic period from Box and Corsham and as far as Bradford-on-Avon in Wiltshire had been used for many hundreds of years, it was the completion of the Box Tunnel on the Great Western Railway in 1841 that led to the great expansion of quarrying in the area. The two most important quarries now operating are at Monks Park, Corsham, which is the remaining example of underground mining in the area; the other is the Hazelbury quarry where the stone is recovered by open cast working. A view of this latter quarry is shown in Figure 5. Figure 6 shows blocks of limestone being hauled to the surface at the Monks Park quarry, from a depth of eighty feet or so below. There are many disused mines in the district like Long Platt mine, Clift mine, Hawthorne mine, Holly Bush mine, Wansdyke, Park Lane, Ridge mine, Elm Park and others, but one of the most famous was St Aldhelm's quarry at Box.

Legend has it that St Aldhelm (645-709 AD) founded the abbey at Malmesbury and chose the stone at Box for building it. He also used it for St Lawrence church at Bradford-on-Avon, one of the oldest churches in England. There are a great number of small opencast quarries, many now disused from which stone for local building has been obtained, and for

Fig. 5 Hazelbury Quarry.

Fig. 6 Monks Park Quarry.
(Photo by permission of Kingston Minerals Ltd)

walling and tiling, stretching right across the stone belt from Bath and Bradford-on-Avon to Malmesbury.

Some limestone was quarried at Swindon, and what is now the Town Garden was once a quarry producing Purbeck-type limestone. Not far away in Okus Road, Portland-type stone of the same age was worked from a quarry, the geological section of which can still be seen. Similar stone was quarried at Brill in Buckinghamshire and may be the northern limit of the Portland and Purbeck beds.

Further south in Wiltshire, stone described as sandy glauconite limestone of the Jurassic Portland beds has for many years been mined at Chilmark. It was used in the thirteenth century for the construction of Salisbury Cathedral. Stone of similar type is still quarried at Tucking Mill quarry to the west of Tisbury, and is particularly valuable for restoration work. Chilmark and Tisbury stone have been used for many local buildings, and particularly churches, like that at Teffont Evias.

Diverting far eastward into Surrey around Godalming, Bargate stone of the Lower Greensand is found. The Lower Greensand occurs between the Wealden clay and the Gault deposits. The stone

Fig. 7 Painswick.

has been obtained from quarries near Godalming, at Compton, Holloway Hill, Huntmore and Northbrook. Bargate stone contains a large amount of sand and in some layers becomes practically a sandstone. It is therefore a very variable material. In Kent from the Hythe beds of the Lower Greensand is an even more siliceous limestone, known as Kentish Rag. It is quarried at Borough Green, and in times past at many places in the Maidstone area from Aylesford in the north to Boughton in the south. It was used by the Romans and can be seen in the lower courses of London Wall. Being very tough the stone is difficult to work. In the fourteenth century Kentish Ragstone from Aylesford was used for the water gate of the Tower of London, for Old St Paul's, Leeds Castle and Eltham Palace. In the weald of Kent from Maidstone to Hindhead cottages built with ragstone can be seen. Stone from the Boughton quarries and from Folkestone quarry was used for Dover Castle in the thirteenth century, and for Sheppey Castle in the following century.

Returning westward into Gloucester one comes back to the Jurassic Oolitic limestone. Important quarries are at Campden, whence stone for the West Front and New Tower of Llandaff Cathedral was obtained; at Naunton, near Cheltenham; at Guiting, which supplied stone for St John's College, Christ Church, and Balliol College, Oxford; at Painswick, whence came the stone for rebuilding St George's Cathe-

dral, Southwark. Painswick stone was, in fact, used as far back as about 1200 for Gloucester Cathedral, and later for All Hallows by the Tower, in London; for the interior of Arundel Castle, and that of York Guildhall; and for new vaulting at the Deanery, Westminster. The town of Painswick, built almost entirely with local stone, is well worth a visit. A fragment is shown in Figure 7. Stone once quarried at Northleach was used for the church of SS Peter and Paul, Northleach, and a nearby quarry at Farmington supplied stone for rebuilding the Inner Temple Church, London.

In Oxfordshire there have been many important quarries of oolitic limestone. Stone from the Bladon quarries was used for the random course walling in the New Bodleian Library at Oxford. Taynton supplied stone in the thirteenth century for Woodstock and in the following century for St George's Chapel, Windsor. Headington stone was used to a great extent in Oxford; for example in the fifteenth century tower of Merton College, and for Magdalen College. Unfortunately Headington stone tends to exfoliate, and decay, and in consequence repairs have had to be made with other limestones like that from Bladon or Clipsham from Rutland. Hornton stone from the Edgehill quarry not far from Banbury is a ferruginous limestone and its brown and blue grey colour is reflected in the appearance of buildings of the district, particularly those in Banbury.

Throughout the whole of the Cotswold area, there are many beautiful towns and villages built practically entirely of the oolitic limestone; places like Broadway with its wide street lined with beautiful stone buildings, Burford,

Fig. 8 Arlington Row, Bibury.

Stow-in-the Wold, Stanway, Bourton-on-the-Water, Lower Slaughter, Painswick and many more. A sketch of some town houses in Painswick is in Figure 7 already referred to. Some smaller cottages at Arlington Row, Bibury, are shown in the sketch in Figure 8. Stone from Burford, of smooth texture, and easily carved, was used by Sir Christopher Wren for interior work at St Paul's Cathedral.

In Warwickshire there are many quarries no longer working, at Bearley, Bidford, Harbury, Grafton Court, Newbold-on-Avon, Princethorpe, Stretton, Upton and other places.

Aynho in Northamptonshire is one of the most beautiful stone villages in England. Further east, near Corby, are the famous Weldon quarries producing oolitic limestone of the Jurassic series, sometimes referred to as Lincolnshire limestone. As early as the thirteenth century, Weldon stone was used in Rockingham Castle, and later for King's College Chapel in Cambridge. The stone is a warm cream to pale buff colour. Another quarry now no longer working producing stone similar to the Weldon variety, was at Kings Cliffe. Not far away is Colleyweston where limestone, the same geologically as Weldon stone, but of a fissile nature, has been quarried extensively and used for roof tiling. The stone is normally quarried in large blocks which are allowed to weather during the winter, with the bedding planes vertical. Rain penetrates between the layers and in frosty weather the expanding ice so formed splits the blocks into plates of suitable thickness for shaping into roofing tiles.

In the village of Barnack, also not far from Stamford, some excellent limestone was quarried as far back as the Roman period, and was later extensively used by the Norman builders. It was used in many early English buildings, as for example the Abbey at Bury St Edmunds, and at Ely Cathedral for some of the carved doorways. Another very famous oolitic limestone comes from quarries at Clipsham near Oakham in Rutland. It is creamy buff in colour, and sometimes has blue patches, and has been used widely in many famous buildings, particularly for repairs and restoration work at several cathedrals like Canterbury, Peterborough, Ripon and Salisbury, and at York Minster; for restoration work at the Houses of Parliament, Buckingham Palace and Hampton Court Palace; and extensively in Oxford at most of the colleges to replace Headington stone which has decayed. Recent buildings using Clipsham stone are the new House of Commons, Guildford Cathedral, and Nuffield College, Oxford.

Continuing to follow the limestone belt into Lincolnshire some other important oolitic limestones (Lincolnshire limestone) deposits are found. At Ancaster the working face of the quarry is up to thirty feet in depth and produces two main types of stone. The stone from the upper layers is a shelly limestone known as Ancaster Weathered, brown and bluish brown in colour and useful for paving. It has a beautiful patterning and when polished is used for interior work. The stone from the lower layers is a more compact stone of medium grain and known as Ancaster Freestone and is particularly suitable for elaborately carved work. A very good type of Lincolnshire limestone is quarried at Ketton, near Stamford. It is fine grained, and although soft when quarried hardens on exposure. It has been used very extensively, and it is only possible to

mention a few of the many buildings where it has been employed. In Cambridge it was used for Wren's Library at Trinity; all the original part of Downing College; and for the colleges of Caius and Gonville, Downing and Emanuel. The façade of the City Hall of Norwich and the chapel at Haileybury College are other examples. It has been used for repair work at Westminster School and, like Clipsham, at Buckingham Palace. The very beautiful tower and spire of the Early English Church at Ketton is built with the local stone. Similar oolitic limestone, referred to as Casterton Freestone or Stamford Freestone, is dug at Casterton. Some layers of this stone, known as Stamford Limestone marble, can be polished and used for interior work.

Lincoln Cathedral is an outstanding example of the use of limestone. The stone comes from the cathedral's own quarry to the north of the cathedral, on the road to Brigg. Several grades of stone are dug; the upper or white bed gives a fine textured stone, easily carved, and the lower or silver bed contains fossils and can be used for paving.

To the west and north, in Derbyshire and Yorkshire and into Westmoreland, there are deposits of carboniferous, or mountain limestone. One quarry is at Coalhill in Derbyshire, but in earlier times many other quarries were worked in Ashover, Buxton, Culver and Crich. Similar stone, light brown to dark grey in colour with fossil markings, is quarried in Deepdale in North Yorkshire, while in Westmoreland at Orton Scar, and Crosby in Ravensworth Fell, carboniferous limestone, fawn or red in colour, with calcite veining is quarried. Incidentally in Wales, the quarry at Penmon, near Beaumaris in Anglesey also produces carboniferous limestone.

Dolomitic, or magnesian limestone from the Permian series is obtained in North Yorkshire. The Huddlestone quarry at Sherburn-in-Elmet, owned by York Minster, is famous. As far back as 1434 this stone was used at York Minster and is being used for the current restoration work. In 1442 it was used in the Henry VII Chapel at Westminster. A quarry at Hovingham, also in North Yorkshire, provides a creamy white oolitic limestone of the Corallian series.

Another type of limestone which should be mentioned is known as 'clunch'. It is a very hard form of chalk containing some calcite, and has been used for many centuries, particularly by church builders for internal work. Having a uniform texture it could be worked and carved easily. However it does not weather well and consequently it has not been used externally to any appreciable extent. Two of the finest examples of its use are the interior of St Mary's Church, Luton, and the beautiful and intricately carved and ornate arcading of the fourteenth century Lady Chapel at Ely Cathedral. The stone occurs sporadically, often as outcrops along the edge of the chalk belt extending from the Chiltern Hills in Buckinghamshire to Hunstanton on the north coast of Norfolk. It was quarried at Totternhoe near Dunstable in Bedfordshire, and in Cambridgeshire at Barrington, Burwell, Cherryhinton, Eversden, Haslingfield, Islesham, Reach and elsewhere. It occurs in outcrops in the west and north-west of Norfolk and has been used locally for the walls of many farm buildings and cottages.

Sandstone Quarries

The most important areas for sandstone are in Salop, Derbyshire, West Yorkshire, and the Forest of Dean (Figure 2). There are however less extensive deposits elsewhere which provide valuable stone for building. There is, for example, the cretaceous sandstone of Sussex, which occurs principally at Fittleworth near Little Bognor in the Hythe beds of the Lower Greensand, and at West Hoathly, near East Grinstead in the Hastings beds of the Wealden series. The town of Horsham is midway between Fittleworth and West Hoathly, and in consequence the sandstone from the neighbourhood is often referred to as Horsham stone. The colour varies from blue-brown to honey. Apart from its use in walls, some of it splits readily to produce paving slabs and more importantly roofing tiles which are in general much thicker and heavier than the well-known Cotswold tiles. Figure 9 shows a house at Ockley near Leith Hill roofed with Horsham tiles. The slabs of stone are laid on a relatively low-pitched roof on account of the weight. Slabs of stone are also placed above the windows and form the roof of the porch. Further east in the North Downs of Surrey there is a calcareous sandstone known as Reigate, Gatton, Merstham, or Malmestone. It was used as far back as the Norman period, often as a substitute for Caen stone from France and much favoured by the Norman builders — but was slightly greyer in colour.

Fig. 9 Horsham tiled roof at Ockley.

Fig. 10 Sandstone wall of Coldharbour, Surrey.

Figure 10 shows a wall at Coldharbour close by Leith Hill in Surrey, to the north of Horsham, consisting of the local sandstone. The random bonding is noteworthy, and the insertion of small fragments of iron slag in the joints, just visible at the upper right-hand side of the photograph, appears to be a local tradition.

The stone can be seen at the Tower of London, for example in the crypt of the Wakefield Tower, in parts of Westminster Abbey and St Stephen's

Chapel, in the crypt of the Guildhall, London, and in many of the old City churches. Large quantities were used for the Palace of Nonsuch, at Cheam, between Sutton and Epsom, built by Henry VIII.

In the Bristol and Forest of Dean areas the Pennant sandstones are very important and widely used. There are a large number of quarries many of which, however, are no longer working. Many years ago the stone was dug in the county of Gloucester at Frampton-Cotterall, Iron Acton, Mangotsfield, Stapleton and Winterbourne. Geologically sandstones of the Forest of Dean belong to the Old Red sandstone (Devonian) and Carboniferous periods. Quarries of Old Red sandstone have been worked between Mitcheldean and Longhope, to the west of Gloucester, and the material used for many local churches and houses. In the Forest of Dean quarries are operating in the Coleford area, at Barnhill producing grey stone, at Bixhead blue stone, and at Cannop grey-pink stone. Barnhill grey stone has been used recently for Berkeley nuclear power station. Many thousands of tons of stone from quarries along the Wye Valley have been used in the construction of the walls protecting the banks of the River Severn and extending almost continuously from Avonmouth to Gloucester. Some of the villages in the Forest of Dean, for example in the neighbourhood of Lydney like Aylburton, built with brown and red sandstone have a rather sombre appearance.

Blue Pennant stone is quarried at Gelligaer Common in Ebbw Vale. It was used in Norman times for building the castle at Caerphilly, a few miles to the south, and that town has many picturesque buildings built of the same material. Further to the west in the Cambrian mountain region the sandstone varies from a silvery grey to a rich purple colour and is well demonstrated at St David's Cathedral and the neighbouring buildings. Stone for the cathedral was obtained locally at Nolton Haven and from the cliffs of Caerfai and Caebwdy.

Returning into England and proceeding northwards into Northamptonshire, sandstone, varying in colour from cream to brown, of the Jurassic system is obtained from quarries operating at New Duston and Moulton. A diversion to the eastern counties to Norfolk reveals a deposit of ferruginous sandstone of the Lower Greensand. It is still quarried at Snettisham and is often known as Carstone. It is golden brown in colour. Similar stone is sometimes quarried where it outcrops in the Isle of Ely. It was used in foundations and in the hearting of walls at Ely Cathedral.

In Nottinghamshire dolomitic or magnesian sandstone is obtained. Two types, white and red, are quarried at Mansfield, the former weathering better than the latter. There is also a true red sandstone. As far back as the middle of the fourteenth century stone quarried close to the castle at Nottingham was used for repairs to that building. In Salop, a whitish grey sandstone of the Triassic period known as Keuper sandstone, has been quarried at Grinshill about eight miles to the north of Shrewsbury. A similar stone was at one time quarried in the Swinney mountain, near Oswestry and in the Bowden quarry near Munslow. Sandstone is widely used throughout the county. Ludlow Castle, on the southern border of Salop, is built with a yellowish-grey

sandstone of the Silurian system and in the Church Stretton area there are many picturesque villages built with similar sandstone, the appearance of which is often enhanced by the purple and greenish streaks within it. The Romans employed the local grey sandstone for building their city of Viroconium at Wroxeter, near Shrewsbury; while Shrewsbury itself has many later buildings which are mostly of red sandstone.

In Cheshire, sandstones of the Millstone Grit series of the Carboniferous system become prominent particularly in the Macclesfield area, where quarries at Kerridge and Rainow are producing stone of varying shades of colour from pink to fawny-grey. All over the West Midlands the Keuper sandstones are abundant, and have been used for many buildings in the Birmingham area and northwards through Newcastle-under-Lyme up to Chester. Here the city and the surrounding villages have many buildings of pink Keuper sandstone, the cathedral providing an excellent example of its use.

In Staffordshire, the famous Hollington stone of the Triassic system is still quarried in considerable quantities at Hollington and Tean a few miles to the northwest of Uttoxeter. There were other quarries, now disused, in the area from Sedgley and Bilston to Stafford, and particularly at Brewood and Tixall. Hollington stone varies in colour from white and pink to red. The pinkish stone was used for Hereford Cathedral, and more recenlty for Coventry Cathedral.

Derbyshire abounds in sandstone and there are in fact so many quarries throughout the Peak District working, and many disused, that it is difficult to select a few to mention here. To the west and north of Matlock there are important quarries at Darley Dale, Birchover, Elton and Stanton Moor; to the north of Bakewell and at Bakewell itself are those at Hathersage and Grindleford; to the south-west of Chesterfield at Wingerworth; at Chinley Moor near Whaley Bridge and at Birch Vale nearer to Stockport. Geologically, the sandstone from all the sites mentioned belongs to the Carboniferous Millstone Grit series, except the Birch Vale and the Wingerworth sandstones which belong to the Carboniferous Coal Measures series.

The stone generally is very durable, and close grained. It weathers well in the industrial cities of the north. Some grades split fairly readily to produce paving slabs and flags for roofing. The latter are heavy rather like the Horsham tiles and are laid at a low pitch. The sandstone ranges widely in colour from pink, yellow, buff, grey to blue and mauve, and has been so widely used that it is difficult to single out any particular examples for special mention. However, as an example, mention might be made of the Birchover sandstone from Darley Dale, which has been used in the construction of the Claerwen Dam in Rhayader, for the Newport Civic Centre, and for the courts and terraces at Nottingham University.

Sandstone of excellent quality abounds throughout the Yorkshire counties, but the largest concentration of quarries now operating is in West Yorkshire. However, there are many quarries often now disused towards the east as near Richmond, particularly on Gatherly Moor; near Boroughbridge; in the neighbourhood of Whitby; and all over the Eastern Moorlands.

The concentration of quarries around Halifax, Huddersfield, Bradford and

Leeds is significant. The sandstone is obtained from two geological strata, the Carboniferous Coal measures, and the Carboniferous Millstone Grit series. Of the former type the stone called Elland Flags is important. The quarries from which it comes are situated not only at Elland Edge and Shepley, near Huddersfield, but at Swales Moor, Southowram and Northowram Hills around Halifax, and at Fairweather Green, Haworth and Eccleshill near Bradford. Some other grades of sandstone from the Coal measures are Gaisby Rock from Bolton Woods, near Bradford, Ackworth Rock, from Ackworth near Pontefract, and Grenoside Rock from Shepley, near Huddersfield. The famous York stone comes mainly from the Shepley area.

Of the sandstones from the Millstone Grit series, the Waterholes Grit from the quarries at Wellfield and Waterholes, near Huddersfield, is important. The Rough Rock from Bramley Fall, near Leeds is also well known and occurs again at Mount Tabor, near Halifax and at Honley and Wellfield near Huddersfield. The quarries at Stancliffe have also produced excellent stone.

York stone is exceedingly hard and durable. Some of it can be split for roofing tiles. Flags are also produced and very widely used for copings, sills, steps and staircases. It has, however, been widely used since early times for paving floors, as in London at Westminster Hall, the rebuilt Guildhall, the Bank of England, the Tower of London and the Royal Palaces. The list is far too long to mention, but other important and more recent buildings of note in which York stone has been used include the Admiralty Buildings, the Royal College of Science, South Kensington, Bristol University, Guildford Cathedral, Huddersfield Town Hall and Manchester Exchange.

The Yorkshire sandstone or Grit stone as it is sometimes called, consists of sand, mainly of quartz or siliceous grains, cemented with silica, iron oxide and carbonate of lime. It ranges in colour from cream, very light brown, golden brown to blue and grey. In very early times it was used at Fountains and Kirkstall, and other Cistercian abbeys in the north of England. In fact many of the stone quarries were owned by the early monks. At Meaux Abbey for example the monks owned a quarry at Brantingham, near Hull, in the twelfth century. Other ancient quarries were at Pontefract, supplying stone for St Stephen's Chapel, Westminster as far back as 1343 and for Windsor Castle the following year. In Nidderdale and Wensley Dale and in the other dales of Yorkshire are many pretty villages, such as Aysgarth, Bainbridge, and Castle Bolton in Nidderdale and Wensley Dale, Arncliffe in Littondale and Burnsall in Wharfdale.

The Millstone Grit, much of it fissile and used for rough walling, paving and roofing, persists throughout the counties north of Yorkshire. In Lancashire there are important quarries of sandstone, at Whitworth, near Rochdale producing blue fissile stone; at Whittle-le-Woods, near Chorley, and at Woolton and Rainhill. Stone from this last quarry, crimson in colour, was used for Liverpool Cathedral. In the county of Durham the creamy brown Dunhouse sandstone from quarries at Winston, near Darlington is important. It was used for the restoration of Durham Cathedral and Castle. Other stone, varying in colour from light buff to brown and grey comes from quarries at Springwell near Gateshead, and at

Stainton and Egglestone, near Barnard Castle. The Blaxter sandstone from a quarry near Elsdon was used at Durham University and for the National Library of Scotland at Edinburgh. Other deposits are still worked in Northumberland at Darney near West Woodburn, at Doddington near Wooler, at Slaley near Hexham, and at Prudham near Fourstones.

In Cumbria, New Red sandstone abounds. It occurs principally in the Penrith area and in consequence is known as Penrith sandstone. It is of Permian age, and bright red in colour; and has been used freely in the town of Penrith with very attractive results. St Bees sandstone of the Triassic period is quarried at Bank End near St Bees. Other deposits of sandstone occur at Kirby Stephen, Kirklinton and Appleby. New Red sandstone has been extensively quarried since the Romans used it for constructing Hadrian's Wall. Many of the buildings in Carlisle are built with it, and from quarries in the neighbourhood of Whitehaven large quantities of sandstone were shipped to Ireland, the Isle of Man and Scotland.

Slate Quarries

The quarries for slates are grouped mainly in three areas of England and Wales (Figure 3).

(a) Devon and Cornwall, particularly along the north coast region, notably at Delabole, although there are many disused quarries along the south coast.

(b) In Cumbria and Lancashire particularly in the Lake District, at Broughton Moor, near Coniston, Buttermere and Burlington near Kirby-in-Furness.

(c) In North Wales from Bangor and Caernarvon veins; in the Nantile Valley; at Dinorwic; Penrhyn and Vronlog; from the Festiniog or Portmadoc veins; and from the Corris or Aberdovey veins, particularly at Machynlleth. Until recently slates were also quarried in the Prescelly mountains close to the Pembrokeshire-Carmarthen border.

Looking at the quarries in more detail, those in Devon and Cornwall will be dealt with first. The largest and most celebrated slate quarries in Cornwall are at Delabole, in the parish of St Teath on the north coast between Stratton and Padstow. The Old Delabole quarry is over a mile round and several hundred feet deep and produces grey to greygreen slates of the Devonian system. The quarry has been worked since the reign of Elizabeth I and large quantities of slate were exported from Port Isaac. The Trebarwith and Trecarne quarries at Delabole produce multicoloured slate, reddish brown and bluegrey.

At Tintagel not far from Delabole a green slate of chlorite phyllite is quarried, and at Lower Penpethy, near Tintagel greygreen and silvergrey slate of the Devonian system is quarried. There are also ancient quarries at Trevalga nearby. In earlier times there were numerous quarries in other areas particularly between Liskeard and the River Tamar, around Lostwithiel, Golant and Fowey.

There are numerous places in Devon where slates have been obtained. Between Plymouth and Tavistock, at Bere Ferres there was a slate quarry operating as far back as the thirteenth century, and there are now quarries working at Moorshop and Mill Hill producing slates of various shades of colour varying from blue to brown. Nearer

Fig. 11 The Nunnery, Dunster.

Plymouth, at Plympton, many slates were produced last century at Cann quarry on the banks of the River Plym. The quarry belonged to the Earl of Morley and the slates were conveyed to Plymouth by canal and railway. There were also many slate quarries between Plymouth and Dartmouth, particularly around Kingsbridge, and in the valley of the River Yealm. At Charleton nearby the quarries were working in mediaeval times.

In Somerset slate was obtained at the Tracebridge quarry, Treborough, and at Oakhampton quarry, Wivelscombe in the Brendon Hills; and further east at Rooks Castle, to the southwest of Bridgewater. Some of the North Somerset slates can be seen cladding the front of the Nunnery at Dunster, shown in Figure 11.

Proceeding northward, at Swithland, east of the Charnwood Forest, large quantities of rather thick and heavy slates were quarried and appear to have been used since Roman times. Further north still in Lancashire, slate quarries, many disused, abound. Blue slate occurs chiefly in the rocky mountainous tracts in the northern parts of High Furness. Well-known Burlington Blue Grey slate is quarried at Kirby-in-Furness. Bursting Stone quarry and Moss Rigg quarry at Tilberthwaite, near Coniston are working and producing the Lakeland Green slates. The Green Buttermere slates of Cumbria are also famous, and produced at the Honister quarry near Keswick, but slates have also in the past been quarried at Bassenthwaite, Borrowdale, Cockermouth and Ulpha. In the western mountains are vast quantities of slate of various colours.

Westmoreland Green slates have been used extensively in many towns. In London, for example, they can be seen at Kensington Palace, St James's Palace, Westminster Hall, Imperial College of Science and Technology, Chelsea Hospital and Queen Mary College. Other quarrying areas are Langdale, Coniston and Ambleside. Kirkstone at the summit of Kirkstone, Brathay near Ambleside, Broughton Moor near Coniston, and Elterwater and Spoutcrag in Langdale are important quarries. The shades of colour of the slates vary from light green, olive green, silvery green and even blue black at Brathay.

Important and extensive slate quarries occur in North Wales, around Blaenau Festiniog, Talysarn, Dinorwic, Bethesda and Corris. In the Blaenau Festiniog area are the quarries of Maen Offeren, Llechwedd and Cwt-y-Bugail producing blue-grey slates. Portmadoc has long been the port of export and to facilitate transport a two-foot narrow gauge line was laid between that town and Dduallt close to Blaenau Festiniog nine and a half miles away. Although the railway has not been used for transporting slates since 1938 it now carries passengers and is known as the Festiniog Railway. It is privately owned. Festiniog is a depressingly grim town of stone cottages and is surrounded by vast heaps of slate waste.

In the Talysarn area the quarry at Twll Llwyd is important, and produces slates of varying shades of colour from green to reddish brown. Nearly all the quarries of Pen-yr-Orsedd and Twll Coed are producing green slates.

The quarries at Dinorwic, not far from Llanberis, another rather drab mountain town with vast quantities of slate waste around it, have been important. In the Bethesda area the Penrhyn quarries are still operating, producing green and grey slates. To the east, in the Horse Shoe Pass near Llangollen,

deep blue slates are obtained from the Clogau quarries. In Montgomeryshire are the Aberllefenni and Braichgoch quarries near Corris producing blue slates.

In all the areas mentioned a great many disused quarries have left unsightly scars on the countryside, which is also disfigured by vast heaps of slate waste.

There is hardly a town or village in England and Wales which does not have some buildings roofed with slate. The material has been so widely distributed that it is difficult to single out any particular buildings for mention.

A block of slate can be easily split by hammer and chisel along the cleavage planes into a number of laminae, and generally the thinner they are, the better is the quality and durability of the tile. The principal minerals present in slates are various compounds of silica and alumina such as chlorites, felspar, muscovite, and quartz, but there may be in lesser quantities others such as magnetitie, pyrites, sulphide of iron marcasite and calcite (calcium carbonate); this last being detrimental if the tiles are to be used in an urban atmosphere, as sulphur fumes may attack the calcite to form calcium sulphate, and in doing so may scale or split the tiles.

Granite Quarries

The term 'granite' is used here in its wide and generally accepted meaning as applied by the stone industry. Dealing first with the group of granite quarries in Devon and Cornwall, their main concentrations occur in the area stretching from Bodmin Moor, down towards the Lizard, and around Dartmoor and the region extending southwards to the coast. Quarries at present operating are listed in Table 5, but there are of course a great many quarries no longer used, or worked out, or only used sporadically. Granite, or moorstone, is also abundant on the surface of the moors and has been used in great quantities since remote times for building houses and churches throughout Cornwall. The remains of many prehistoric structures in the form of hut circles, built with blocks of granite, have survived. One of the better examples is to be seen at Chysauster which certainly dates back to the second century BC. A sketch of it is shown in Figure 19.

Most of the Cornish granite is silver grey in colour and of medium or fine grain. As with most igneous rocks the material is not easily cut, or dressed, but with modern appliances it can be cut into relatively thin slabs and polished, and used for the decorative cladding of buildings. One example of this use is seen at the Trades Union Congress memorial building in London. Tor Down granite from St Breward, Bodmin was used. Generally, however, granite is used in large rectangular blocks with rough hewn surfaces, with little decoration. Notable examples of its use are old Waterloo Bridge, now demolished, built with Penhryn granite, and almost all the more recent Thames bridges from Tower Bridge to Kew; and for the South Bank also using Penhryn granite. Bridges in other parts have employed granite, as for example the Severn Bridge, linking Aust with Chepstow where granite from the De Lank quarry at St Breward, Bodmin was used for the copings to the piers and cutwaters; and material from the same source was used for the bridge over the Tamar spanning between St

Brideaux and Saltash and linking Devon and Cornwall.

Other buildings of note built with Cornish granite are the Metropolitan Cathedral in Liverpool and Central Hall, Westminster where material from the Pelastine quarry at Penhryn was used. Although the granite in the examples quoted was silver grey in colour, several other varieties have been worked, but not very extensively. Luxulyan granite composed of black tourmaline and pink felspar was used for the Wellington Sarcophagus in St Paul's Cathedral, London.

The area around Plymouth on the border between Cornwall and Devon, and on Dartmoor, abounds in granite quarries many of which are no longer worked. Some of the quarries are very ancient. Transportation of the heavy granite blocks has always been a problem, and to facilitate this Sir Thomas Tyrwhitt had a railroad track laid at the beginning of the last century, which enabled the material to be carried from the Princetown area of Dartmoor, down to the Sutton Pool in Plymouth, a distance of twenty-four miles, whence it could be conveyed by boat to its required destination. There are big granite quarries in the Ashburton district of Dartmoor. Those to the east of Haytor Rocks, near Bovey Tracy provided the stone, over a hundred years ago, for the British Museum and General Post Office in London, and for London Bridge, now demolished. The granite was conveyed to London by boat from Teignmouth, having been brought down from the quarries on a tramway, built in 1820, a distance of six miles, to the head of a canal constructed in 1794. Thence it was shipped by barge to Teignmouth. The tramway is no longer in use.

The origin of the vast granite mass of Dartmoor is of great interest. It was formed by the cooling and solidification of lava derived from deep down in the earth, and once fed the Carboniferous and Post Carboniferous volcanoes of Devon.

Granite of a different colour is found in parts of the Midlands and North of England. Red Granite occurs at Mountsorrel in Leicestershire while in Westmoreland the famous Shap granite, a porphyritic granite, varying in shades of colour from brownish red to greyish pink, has provided material for many important works throughout Britain, such as the Queen Elizabeth II Dock, Manchester Ship Canal, and the King George V Graving Dock at Southampton. The main quarries are situated about three miles south of Shap, but from Kendal in the south to Wasdale Crag in the west, and throughout Cumbria, there are many outcrops of granite.

In Wales porphyritic granite, grey or bluish grey in colour is quarried in Merioneth at Arenig near Bala, and in Caernarvonshire at the Eifi quarry at Trevor. This latter granite was used in the construction of locks for the Mersey Docks and Harbour Board at Liverpool.

The Mason's Craft

The mason's craft is one of the oldest and most important of the building crafts. The masons were broadly of two grades, mason hewers (cissores) or cutters (taylatores) and mason layers (legers) or setters (positores). The hewers were adept with the mallet and chisel, working and carving freestone, ie limestone and the finer grained sandstone, in which case they were often

called freemasons. In distinction to these freemasons were the hard hewers who were concerned with the preparation of some of the much harder, tougher and intractable varieties of stone like Kentish ragstone. The layers, sometimes called rough masons, or rowmasons (cubitores) were concerned with the preparation of stone, often in the quarry, by hammering or scappling, instead of by cutting with a chisel. On this account they were sometimes called scapplers (batrarii). The layers or setters also laid the stones in the walls, and when doing this they were sometimes referred to as wallers (muratorii) to distinguish them, for example, from the paviors (pavores), whose job it was to lay stone paving. Generally the masons worked in lodges, or workshops, on the building site, under the supervision of the mastermason (magister cementariorum). Strict rules of conduct were laid down, particularly for the apprentices, who after years of training could become journeymen, and in course of time a selected few of them might become mastermasons. The lodge was very much a training ground in craftsmanship, and it was possible for a rough mason, for example, to gain experience and skill and become a freemason. To become a master of his craft a journeyman would have to demonstrate his skill and ability, often by producing a 'masterpiece' of work.

The mastermason was usually responsible for the details of the stonework. He could make rough sketches, plans and elevations, which could be understood by his men; he could estimate quantities of materials, and supervise the workmen. A mastermason, after years of experience, might assume very great importance by becoming a king's mason (cementarius regis). Henry de Yevele (1319-1399) having been a mason for thirty years, mainly at Westminster Abbey, was an excellent example of this attainment. He became king's mason or 'devisor' of masonry, a position, it would seem, akin to an architect. Apart from having oversight of the king's palaces and castles, he acted as adviser or consultant on a number of projects. He served, for example, on the commission which advised on the reconstruction of Rochester Bridge. The building of Guildhall, London, was another project on which he advised. In 1356 he served on a committee which drew up regulations for London masons. He, like some other masons and mastermasons, was also a contractor supplying building stone. This was not such an unnatural thing for masons to do, since not only did some of them open up stone quarries on their own account and hew the stone, but they often worked and shaped the blocks at the quarries and were able to supply prepared material to the building sites in the particular shapes and sizes required, leaving the final dressing and carving to be done on the site.

King Henry III employed several mastermasons, whose responsibility it was to select and supervise groups of masons, and other staff, for particular tasks. They were privileged to wear robes presented to them by the king as a mark of their important office. This practice continued through the mediaeval period. Stonemasons were highly respected people, and often the craft was handed down through successive generations. A few families of stonemasons might be mentioned. The Arnolds, established near Ilminster, were probably typical of provincial families engaged in building crafts.

John and William Arnold worked on the building of Wadham College (1610-1613). William was a mastermason, who prepared plans and superintended the building workers. At a later date a member of the Arnold family was first engaged by Inigo Jones, and then by Wren as a carver at St Paul's Cathedral. Another family of builders were the Strongs. Timothy Strong from Barrington, near Burford, was the contractor for Cornbury Park, Oxfordshire (1632-1633), designed by Nicholas Stone, the architect. Valentine Strong, son of Timothy, and Simeon Strong were engaged in 1634 on the building of St John's College, Oxford (1631-1636) and Thomas Strong, grandson of Timothy, owned the stone quarries at Burford, and was a mastermason working under Wren in the building of St Paul's Cathedral. As Burford stone was used there by Wren, it may be that Thomas Strong supplied some of it from his quarries.

Another family of stonemasons were the Grumbolds who owned quarries at Weldon, Northamptonshire. Arthur Grumbold (1603-70) was one of the earliest. He lived in a house in the main street of Weldon which still stands, and bears his initials and the date 1654. One branch of the family went to the quarrying village of Raunds, near Higham Ferrers. Another member of the family was Thomas Grumbold who lived at Cambridge. It was he who built the east and south ranges of Clare College, Cambridge (1638-1642), in the Perpendicular style. Robert Grumbold (1639-1720) his successor, directed the works at Trinity College Library, Cambridge, from 1676 to 1682, working to Wren's design. He also built part of the west wing of Clare College, Cambridge, in 1662-1672, again in the

Fig. 12 Haunt Hill House at Weldon; the home of Humphrey Frisbey, mastermason.

Perpendicular style. The Grumbolds at Weldon were related to another family of stonemasons, the Frisbeys. Elizabeth Grumbold married Humphrey Frisbey the son of another Humphrey Frisbey, a stonemason working at nearby Kings Cliffe. The house in which Humphrey Frisbey lived, which he built in 1643, is still standing, and is known as Haunt Hill House, Weldon. On the south gable are carved the arms of the Mason's Company, and the builder's initials H.F. The house, built of Weldon stone from his own quarry, is shown in the sketch in Figure 12.

The mastermason eventually assumed the status of building contractor, owning the quarries, working the stone, transporting it to the building site and incorporating it in the structure. The well-known contracting firm of John Mowlem developed in this way. John Mowlem, founder of the firm, born in 1798 at Swanage, Dorset, came from a stone-quarrying family. At the age of eighteen he became apprenticed in London to Henry Westmacott, a prominent stonemason and brother of the sculptor Sir John Westmacott. By 1816, he had risen to be foreman for Westmacott and worked on many monumental structures such as the Achilles statue in Hyde Park, the statue of Charles James Fox in Bloomsbury Square, Nelson's tomb in St Paul's Cathedral and on various buildings such as Carlton House and Greenwich Palace, where he supervised the work on the exfoliated capitals for the King Charles Quadrangle. About 1832 John Mowlem started business on his own account selling Purbeck paving slabs, shipped by his quarrying relatives at Swanage to his wharf in London at Pumber Basin, where Victoria Station now stands. The business prospered and the wharf was moved to Paddington Basin, where John Mowlem imported large quantities of granite chips which were used on London's roads, in addition to the importation of the stone from Purbeck.

Methods of stone quarrying and stone working have changed but little in course of time. Picks, bars and wedges are still used for quarrying the sedimentary stone, as they were many centuries ago, advantage always being taken of the natural bedding planes as the best positions for splitting it. Once the upper surface and one side of an unhewn block has been exposed, it then remains for it to be split off from the back and the other side with wedges, and finally prized off its natural bed. It is then sawn into blocks of convenient sizes and sent to the mason's yard. The igneous rocks have no natural uniform beds and can only be hewn or blasted out in irregular blocks. These are either split with wedges or feathers, or cut by mechanically operated toothless iron bandsaws fed with chilled iron shot. The dressing of the stone is carried out with tools of various types, including the axe, the gab, the scabber, the puncheon, and plain and serrated chisels of different sizes.

To utilize the stone to the best advantage from the point of view of strength and resistance to weathering, it is customary to lay it on its natural bed, if it has one, or in such a way that the natural bed is set at right angles to the direction of the thrust. The stone voussoirs of an arch for example are cut and placed so that their natural bedding planes lie radially.

In Figures 13 to 18 are shown the main types of bond used today in stone walls. The common, rough uncoursed, or random rubble wall shown in Figure

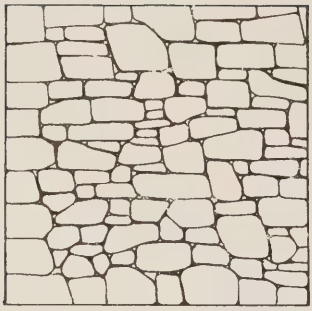

Fig. 13 Common rough uncoursed or random rubble.

Fig. 14 Random rubble built to course.

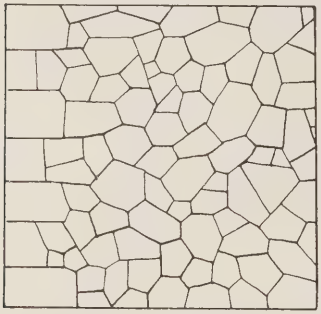

Fig. 15 Polygonal random rubble with hammer-dressed joints.

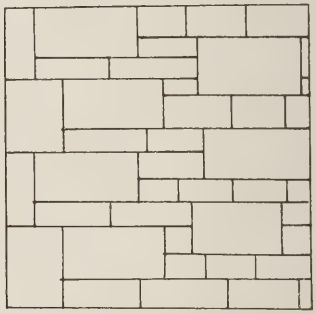

Fig. 16 Irregular coursed, snecked or squared random rubble.

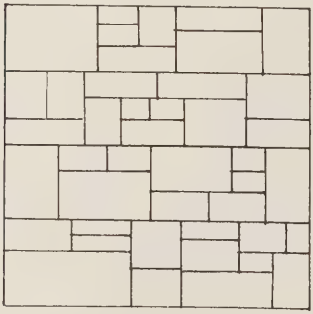

Fig. 17 Random rubble built to courses with beds horizontal and joints vertical.

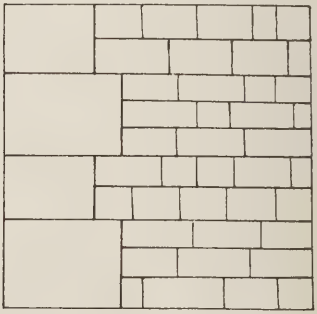

Fig. 18 Coursed rubble.

13, is made of odd-shaped pieces of rock, very often pieces of naturally weathered rock, and it is probably only at the quoins that they need to be dressed. Random rubble, built to course, as shown in Figure 14, makes a stronger wall. Intractable rocks, ragstone and granite for example which fractures into odd shapes can be utilised in polygonal random rubble. In the best work the surfaces are hammer dressed to give close joints as shown in Figure 15. Random rubble walls in which the stones are squared but of irregular size, with small stones or snecks introduced to break the course, as shown in Figure 16, are common in Scotland and this type of work is called snecked rubble. Squared random rubble brought to course is shown in Figure 17, and the last example in Figure 18 shows coursed rubble of squared stone laid in courses to suit the heights of the cornerstones, or rybats.

The work involved in preparing stone blocks for building is considerable and costly, and it is now common practice, even in areas such as the Cotswolds where natural stone is so prolific, for the stone to be crushed at the quarry and used with a binding material, such as Portland cement, to produce precast blocks.

Surface Stones and Erratics used for Building

There are many erratics* and surface stones which have been used locally for building. This is particularly so in the

* The term 'erratics' is applied to the large pieces of stone and boulders which have been transported from their original location. This may have occurred by glacial action or by denudation by flooding.

Fig. 19 Prehistoric house at Chysauster, Cornwall.

moorland areas of Devon and Cornwall, Cumbria and Wales. Many examples of prehistoric hutments and megalithic structures can be seen, notably on Dartmoor. The stone houses at Chysauster, Cornwall, one of which is shown in Figure 19, were erected during the period 200 BC to 300 AD. Here the walls are dry built using boulders of granite gathered from the surface of the moors.

In some chalk areas, as in Wiltshire, there are many sarsens, large sandstone boulders, often known as Druid stones or Bride stones, which have been left on the surface after erosion of the soil and chalk. They are particularly prolific on the surface of the downs, or half buried, in an area called Grey Wethers near Marlborough, and in the valleys around the Fyfield Downs. The stones have been used in many houses and farm buildings in the Avebury and West Overton area. Some of the very large Sarsens, often weighing many tons, were transported for use at Stonehenge, for the Avebury prehistoric circle and the West Kennet long barrow. In years past there was quite an industry carried out on the downs, to break up the sarsens to produce building blocks, while small pieces were shaped and used in neighbouring towns like Swindon, Marlborough and Devizes for curbing stones and cobbles. The so-called 'blue stones' at Stonehenge are similar geologically to material in the Prescelly mountains of South Wales, and were most likely eroded from that area and carried southward by glacial action.

In East Anglia where there is a dearth of building stone, flint walling has been used since the Roman occupation. The walls were built with layers of flint nodules bedded in lime mortar,

Types of flint walling from Cromer, Norfolk

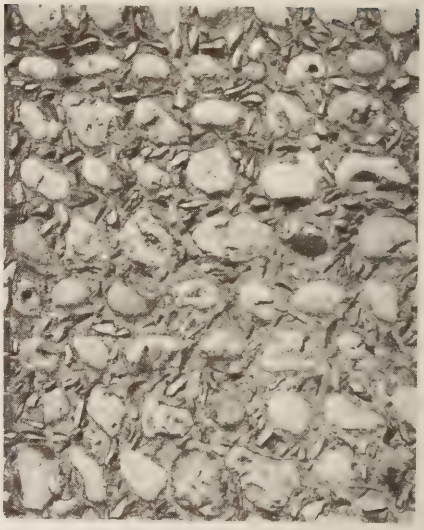

Fig. 20 Undressed flints galleted joints.

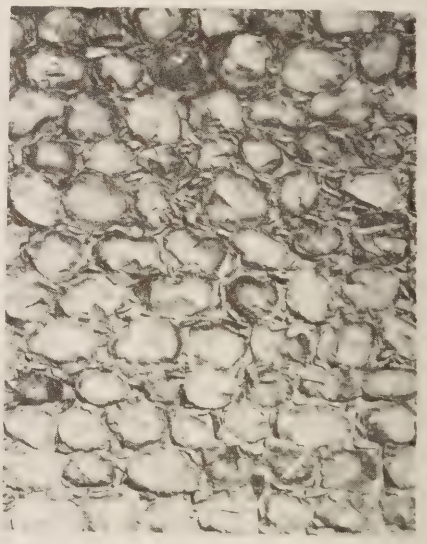

Fig. 21 Knapped flints with galleted joints.

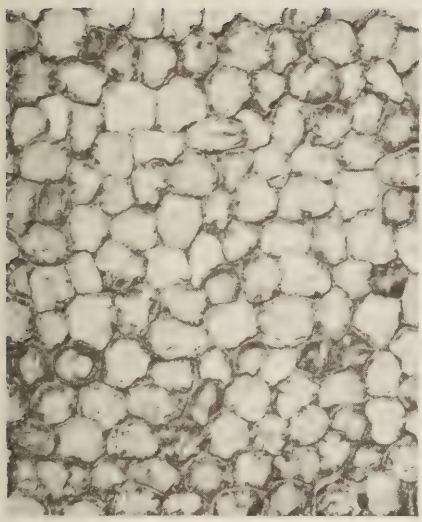

Fig. 22 Knapped flint walling.

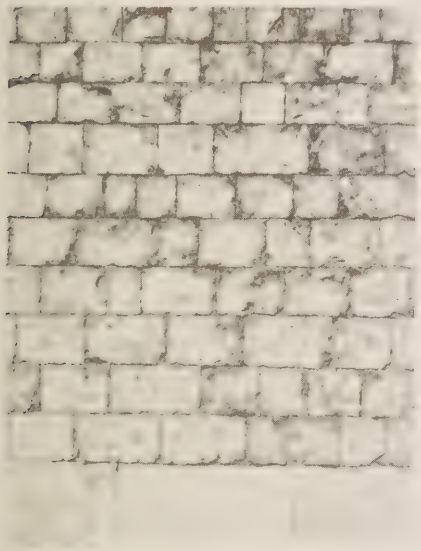

Fig. 23 Square flint walling.

sometimes split to give a fair face. The finest flintwork is to be seen in Suffolk and Norfolk, the home of flint knapping. The freshly knapped flints derived from the chalk are grey in colour. The example shown in Figure 23, at the parish church of SS Peter and Paul, Cromer, is of the Early Perpendicular period and shows how skilfully the flints were squared so that they could be laid and fitted together with the thinnest of joints. Three other types of flint walling, also at Cromer, show in Figure 20 undressed flints set with galleted joints, in Figure 21 knapped nodules also laid in courses with galleted joints, and in Figure 22 knapped flints skilfully laid in reticulate pattern. The craft of flint knapping for facing rubble walls, flourished in the fifteenth and sixteenth centuries. In East Anglia great use was made also of flint for decorative infillings in association with stonework on walls and buttresses. The gatehouse of the historic priory of St Osyth's, Colchester, is one of the finest examples of this technique; but flint chequered work is also excellent on the walls of the Guildhalls at Kings Lynn and Norwich. In the chalk areas of the southern counties, well away from the coast, it is not uncommon to see chequered flint and chalk walls for cottages. In Wiltshire there are numerous examples in the villages around Salisbury such as Tilshead, Shrewton and Fittleton.

All around the coast can be seen many instances of the use of undressed flints. The flints from the seashore are usually ochreous in colour, but inland, the field flints are whitish or grey.

In conclusion, reference must be made to the hundreds of miles of dry stonewalling erected to surround the fields. They abound across Dart-

moor and Exmoor, and all through the Cotswold and limestone area; in Wales, the Lake District, Derbyshire, Yorkshire and further north in Cumbria. Drystone walling is a subject to be studied separately, involving as it does great skill in execution. The techniques vary throughout the country and the two illustrations in Figures 24 and 25 serve merely to demonstrate this point. Figure 24 shows a drywall in the Lake District composed of irregular sandstone blocks interlaced with slates, whereas Figure 25 illustrates the type of wall erected with limestone blocks throughout the Cotswold area.

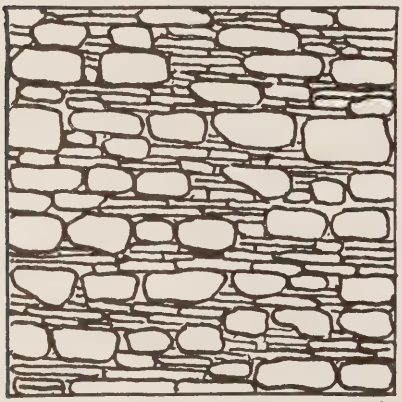

Fig. 24 Lakeland drywall.

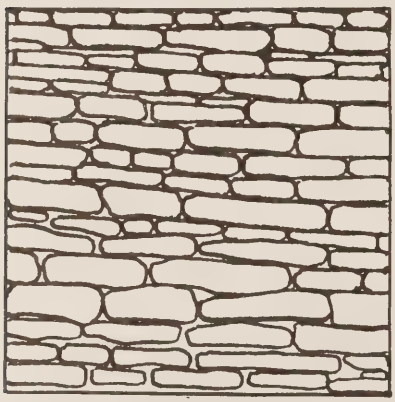

Fig. 25 Cotswold drywall.

Appendix

Distribution of Quarries

The outline maps in Figures 1, 2 and 3 show the distribution of stone quarries in England and Wales. The limestone quarries are indicated as 'circles', the sandstone quarries as 'squares', the granite quarries as 'triangles' and the slate quarries as 'diamonds'. Tables 2 to 5 list many of the main quarries still in operation. For more comprehensive and detailed information on working quarries in Great Britain, reference should be made to the *Natural Stone Directory* compiled and published by Park Lane Publications Ltd, London. Many quarries are no longer operating, or if so sporadically. Some of these are very ancient and important historically, and are mentioned in later tables.

Samples of building stones can be seen in the Geological Museum at South Kensington.

A glance at the maps shows that the igneous rocks occur mainly in the western parts of England and Wales, from Cornwall to Cumbria. The sandstones occur for the most part between the igneous rocks and the main limestone range which forms the backbone of England extending practically continuously from Devon to North Yorkshire. To the east of the limestone range the country has very little stone available for building.

A geological classification of building stones at present being quarried is given in Table 1 below. The numbers refer to the particular stones listed in Tables 2, 3, and 4 following.

Table 1. Geological classification of building stones

	Geological System	**Limestone** (see Table 2)	**Sandstone** (see Table 3)	**Slate** (see Table 4)
Quaternary	Pleistocene			
Tertiary	Pliocene Miocene Oligocene Eocene			
Mesozoic	Cretaceous	43.	1,2,3,9.	
	Jurassic	2,3,5,6,7,8,9 10,11,12,13,14, 15,16,17,18,19, 20,21,22,23,24, 25,26,27,28,29, 30,31,32,33,34, 35,36,37,38,39, 40,41,42,47.	7,8.	
	Triassic		10,15,16,62.	
Palaeozoic	Permian	45.	17,60,61.	
	Carboniferous	1,4,44,46,48.	4,5,6,11,12,13, 14,18,19,20,21, 22,23,25,26,27, 28,29,30,31,32, 33,34,35,36,37, 38,39,40,41,42, 43,44,45,46,47, 48,49,50,51,52, 53,54,55,56,57, 58,59,63,64,65, 66,67,68.	
	Devonian			1,2,3,4,5,6,7,
	Silurian			8,18,21.
	Ordovician			9,10,11,12,14, 19,20,22,23,24, 25,26.
	Cambrian			13,15,16,17.

Table 2 Limestone quarries still being worked

County		Building Stone	Location
Somerset	1	Battscombe	Cheddar
	2	Box Ground	Box
	3	Blue Lias	Charleton Mackrell
	4	Cheddar	Westbury-sub-Mendip
	5	Combe Down	Bath
	6	Doulting	Doulting
	7	Ham Hill	Ash
	8	Stowey	Bishop Sutton
Dorset	9	Portland Roach	Portland
	10	Portland Stone	Portland
	11	Portland	Sheat
	12	Purbeck	Langton Matravers
	13	do	do
	14	do	do
	15	do	Worth Matravers
	16	do	do
	17	do	do
	18	do	Herston
	19	do	Swanage
Wiltshire	20	Chilmark	Tisbury
	21	Tisbury	West Tisbury
	22	Monks Park	Corsham
Gloucestershire	23	Campden	Campden
	24	Cotswold	Cirencester
	25	do	Naunton
	26	Guiting	Guiting
Oxfordshire	27	Bladon Cotswold	Bladon
	28	Hornton	Edgehill
	29	Taynton	Taynton
Northants	30	Weldon	Weldon
	31	Colleyweston	Colleyweston
	32	do	do
	33	do	do
Cambridgeshire	34	Walling Stone	Helpston Heath
	35	do	Yarwell
	36	do	Wansford
	37	do	do
Leicestershire	38	Clipsham	Oakham
	39	do	do
Lincolnshire	40	Ancaster	Ancaster
	41	Ketton	Ketton
	42	Casterton	Stamford

Table 2 (continued)

County		Building Stone	Location
Kent	43	Kentish Rag	Borough Green
Derbyshire	44	Derbyshire Fossil	Coalhill
North Yorkshire	45	Huddleston	Sherburn-in-Elmet
	46	Deepdale	Dentdale
	47	Hovingham	Hovingham
Cumbria	48	Orton Scar	Orton Scar

Table 3 Sandstone quarries still being worked

County		Building Stone	Location
West Sussex	1	Sussex Sandstone	Little Bognor
	2	do	West Hoathly
	3	Wealden Sussex	do
Gloucestershire	4	Forest of Dean	Barnhill
	5	do	Cannop
	6	do	Coleford
Northants	7	Duston	New Duston
	8	Moulton	Moulton
Norfolk	9	Carstone	Snettisham
Salop	10	Grinshill	Wem
Cheshire	11	Kerridge	Kerridge
	12	do	do
	13	do	do
	14	Rainow	Rainow
Staffordshire	15	Hollington	Hollington
	16	do	do
Nottingham	17	White Mansfield	Mansfield
Derbyshire	18	Birchover	Stanton Moor
	19	Chinley Moor	Hayfield
	20	Darley Dale	Darley Dale
	21	Hall Dale	do
	22	Watts Cliff	Elton
	23	Derbyshire Grit Stone	Birch Vale
	24	Davie Blocks	Bakewell
	25	Delph	Wingerworth
	26	Millstone Edge	Hathersage
	27	Stoke Stone	Grindleford

Table 3 (continued)

County		Building Stone	Location
Great Manchester	28	Britannia	Whitworth
Lancashire	29	Revidge Grit	Chorley
West Yorkshire	30	Bolton Wood	Bradford
	31	do	do
	32	do	do
	33	Hard Rock	Halifax
	34	Yorkshire Delph	Fairweather Green
	35	Yorkshire Flagstone	Bradford
	36	Elland Edge	Southowram
	37	Hard York	Halifax
	38	Hard York Freestone	Northowram
	39	Ringby	Swalesmoor
	40	Yorkshire Freestone	Mount Tabor
	41	York	Rawdon
	42	York Stone	Southowram
	43	do	do
	44	Yorkshire Stone	Halifax
	45	Crosland Hill	Southowram
	46	Greenmoor	Shepley
	47	Hard York	Crosland Hills
	48	Lane Head	Shepley
	49	Waterholes	Waterholes
	50	Wellfield	Wellfield
	51	Bramley Fall	Leeds
	52	Woodkirk	Morley
	53	Elland	Rastrick
	54	York Stone	Holmfirth
Durham	55	Dunhouse	Winston
	56	Stainton	Stainton
	57	Windy Hill	Egglestone
Tyneside	58	Springwell	Springwell
Cumbria	59	Lazonby	Lazonby
	60	Penrith Red	Stonerays
	61	Red St Bees	St Bees
Northumberland	62	Ladycross	Slaley
	63	Blaxter	Elsdon
	64	Darney	West Woodburn
	65	Prudham	Fourstones
	66	Doddington	Wooler
Mid Glamorgan	67	Rassau	Rassau
	68	Pencaemaur	Gelligaer
Dyfed	69	Caerbwdy	St Davids

Table 4 Slate quarries still operating

County		Building Stone	Location
Cornwall	1	Cornish Rustic	Lower Penpethy
	2	Delabole	Delabole
	3	Trebarwith Rustic	do
	4	Trecarne Rustic	Trecarne
	5	Tredinnick Rustic	Tredinnick St Issey
Devon	6	Mill Hill	Mill Hill, Tavistock
	7	Longford Rustic	Moorshop, Tavistock
Clwyd	8	Berwyn	Clogau, Horse Shoe Pass
Gwynedd	9	Blue Grey Slate	Aberllefenni, Corris
	10	Blue Welsh Slate	Braichgoch, Corris
	11	Cwt-y-Bugail	Blaenau-Festiniog
	12	Maen Offeren	do do
	13	Pen-yr-Orsedd	Nantile
	14	Llechwedd	Blaenau-Festiniog
	15	Twll Coed Green	Nantile
	16	Penrhyn	Bethesda
	17	Twll Llwyd	Twll Llwyd
Cumbria	18	Burlington Blue Grey	Kirby-in-Furness
	19	Lakeland Green	Coniston Old Man
	20	do do	Moss Rigg, Tilberthwaite
	21	Brathay	Ambleside
	22	Broughton Moor	Coniston
	23	Spoutcrag	Langdale Valley
	24	Elterwater	do do
	25	Kirkstone Green	Kirkstone Pass
	26	Buttermere	Honister

Table 5 Granite quarries still operating

County	Building Stone		Location
Cornwall	1	Bosahan	Constantine
	2	Clywoon	do
	3	De Lank	St Breward
	4	Hantergantick	do
	5	Tranack	Mabe
	6	Trevone	do
	7	Trenoweth	do
	8	Trolvis	Longdowns
Devon	9	Merrivale Devon Grey	Merrivale
Gwynedd	10	Arenig	Arenig
	11	Trevor	Trevor
Cumbria	12	Shap	Shap

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